https://dx.doi.org/10.1016/j.jclepro.2018.07.318

Influences of barriers, drivers, and promotion strategies on green building technologies adoption in developing countries: The Ghanaian case

Amos Darko [a,*], Albert Ping Chuen Chan [a], Yang Yang [a], Ming Shan [b], Bao-Jie He [c], Zhonghua Gou [d]

[a] Department of Building and Real Estate, The Hong Kong Polytechnic University, 11 Yuk Choi Rd, Hung Hom, Kowloon, Hong Kong

[b] School of Civil and Engineering, Central South University, 68 South Shaoshan Road, 410075, China

[c] Faculty of Built Environment, University of New South Wales, Kensington 2052, NSW, Australia

[d] Cities Research Institute, School of Environment, Griffith University, Gold Coast, QLD 4215, Australia

Abstract

Adopting green building technologies (GBTs) is critical to implementing sustainability within the construction industry. Many barriers, drivers, and promotion strategies influence the GBTs adoption. Appreciating these barriers, drivers, and promotion strategies and how they influence GBTs adoption is core to the successful promotion of GBTs adoption. However, there appears to be no studies developing quantitative models to explain how various types of barriers, drivers, and promotion strategies influence GBTs adoption, especially in developing countries such as Ghana. This research aims to investigate and model the influences of various types of barriers, drivers, and promotion strategies on GBTs adoption in Ghana. Data were collected through a questionnaire survey with 43 professionals with green building experience. Partial least squares structural equation modeling (PLS-SEM) was used to analyze the data. The results showed that:

* Corresponding author.
E-mail addresses: amos.darko@connect.polyu.hk (A. Darko), albert.chan@polyu.edu.hk (A.P.C. Chan), jackie.yyang@polyu.edu.hk (Y. Yang), ming.shan@csu.edu.cn (M. Shan), baojie.unsw@gmail.com (B.J. He), z.gou@griffith.edu.au; gouzhonghua@gmail.com (Z. Gou).

(1) government-related barriers have a significant negative influence on GBTs adoption; (2) company-related drivers have a significant positive influence on GBTs adoption; and (3) two promotion strategies – “government regulations and standards” and “incentives and R&D support” – would have significant positive influences on GBTs adoption. In conclusion, this study highlights the need to reinforce the government’s participation in the promotion of GBTs adoption. The findings can help policy makers and practitioners promote GBTs adoption in the construction industry. Based upon the results, an implementation strategy (IPS) to help promote GBTs adoption is proposed. Regarding the quantitative influences of barriers, drivers, and promotion strategies on GBTs adoption, the findings of this study are arguably the first to be presented for the construction industry, and therefore contribute to the existing green building body of knowledge.

Keywords: Green building technologies; Barriers; Drivers; Promotion strategies; Developing countries; Structural equation modeling.

1. Introduction

The construction industry has significant environmental, social, and economic impacts on the community. For example, the construction industry is responsible for more than 40% of the total global energy consumption and accounts for more than 40% of the global greenhouse gas emissions (International Energy Agency (IEA), 2013). Reducing these impacts could play a significant role in sustainable development. Hence, green or sustainable building has captured the attention of construction experts and researchers around the world and has been promoted by numerous governments (Zuo and Zhao, 2014). Green building is “the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building’s lifecycle” (US Environmental Protection Agency (USEPA), 2016). To successfully implement green building, it is necessary to adopt green building technologies

(GBTs). Typical examples of GBTs are solar technology and green roof technology (Zhang et al., 2011).

Many barriers, drivers, and promotion strategies influence GBTs adoption. Understanding these barriers, drivers, and promotion strategies is of key importance to the promotion of GBTs adoption. Thus, several studies have been carried out to analyze the barriers (e.g., Zhang et al., 2011; Chan et al., 2016), drivers (e.g., Love et al., 2012; Darko et al., 2017a), and promotion strategies (e.g., Darko et al., 2017a; Chan et al., 2017) of GBTs and practices adoption. In spite of their undoubted value, these studies have some limitations that need to be addressed in order to promote and accelerate the more widespread adoption of GBTs within developing countries. It is worth noting that the adoption of GBTs has been slower within developing countries than within developed countries (Mao et al., 2015; Darko and Chan, 2018). As alleged by the World Green Building Council (WorldGBC) (2018), "different countries and regions have a variety of characteristics such as distinctive climatic conditions, unique cultures and traditions, diverse building types and ages, or wide-ranging environmental, economic and social priorities – all of which shape their approach to green building." In addition, GBTs and practices adoption is an effort that has the potential to contribute towards achieving sustainability, and Kates and Clark (1999) and Hosseini et al. (2018) contended that sustainability has a context-specific nature, as society's developmental goals must be realized in efforts to achieve sustainability. These issues suggest that green building is not the same across the globe, and that it is essential to understand how GBTs and practices adoption can be promoted within specific countries and regions so as to achieve sustainability. Analyzing the barriers, drivers, and promotion strategies of GBTs and practices adoption plays a crucial role in understanding how to promote the GBTs and practices adoption. However, research relating to the barriers, drivers, and promotion strategies of GBTs adoption in developing countries such as Ghana has been inadequate, as evinced by Darko and Chan (2016) and Darko et al. (2017b). Moreover, existing studies on the barriers, drivers, and promotion strategies of GBTs and practices adoption appear to be predominantly based upon qualitative and descriptive analyses (Love et al., 2012; Durdyev et al., 2018), and as such there still remains very little knowledge about the quantitative influences of various types of barriers, drivers, and promotion strategies on GBTs adoption in the construction industry. Researchers, policy makers, industry practitioners and stakeholders, as well as advocates are interested in not only which GBTs adoption barriers, drivers, and promotion strategies are more critical or important, but also which barriers, drivers, and promotion strategies are significantly correlated to GBTs adoption. Ning (2014) examined the quantitative influences of barriers and drivers on network strategies adoption in construction projects and indicated that such an examination is beneficial to the successful adoption of network strategies. It is therefore worthwhile to carry out a similar examination within the context of GBTs adoption in the construction industry.

Furthermore, despite structural equation modeling (SEM) receiving considerable attention in construction research (Xiong et al., 2015), Onuoha et al. (2018) pointed out that it is hard to find green building-related studies that are based on SEM. In particular, with respect to Ghana, such kind of studies are nonexistent. The present research applies partial least squares structural equation modeling (PLS-SEM) to develop quantitative models to elucidate the influences of various types of barriers, drivers, and promotion strategies on GBTs adoption.

In the light of the above background, this study aims to examine and model the quantitative influences of various types of barriers, drivers, and promotion strategies on GBTs adoption in the construction industry with reference to Ghana. This study is significant because its findings could be useful in at least two ways. First, the findings on barriers and promotion strategies can help policy makers, industry stakeholders, and advocates develop proper strategies to promote GBTs adoption. Second, the findings on drivers may guide the GBTs adoption decision-making of practitioners and companies. As the studies investigating the influences of barriers, drivers, and promotion strategies on GBTs adoption are scarce, this research expands the existing green building literature through proposing a framework that explains how various barriers, drivers, and promotion strategies influence the GBTs adoption. Likewise, with the help of the findings of this study, foreign and international organizations as well as advocates seeking to implement and promote GBTs within Ghana could possess prior practical knowledge of issues that might influence their activities and prepare for them. Ultimately, this research benefits the sustainable development of the construction industry in general.

Although the adoption of GBTs in Ghana has been slow and still in its early stages, Ghana remains one of the few developing countries that are making attempts to achieve major progress in the adoption and implementation of GBTs. For instance, Ghana has successfully launched the first LEED-certified green hospital in Africa, which is the Ridge Hospital (Bubbs, 2017), and the first green commercial office building in West Africa, which is the One Airport Square (ArchDaily, 2015). Various GBTs, e.g., solar water heating technology, rainwater harvesting technology, and natural ventilation technology were implemented in these projects. These show that Ghana provides a good context for research to understand the typical GBTs adoption issues within a typical developing country. Thus, although this study is focused on Ghana, the findings and implications might be of benefit to policy makers in other (especially developing) countries worldwide. Moreover, this study's methodology and framework can be used in other countries and could assist in better understanding which issues should be highlighted in GBTs adoption and promotion activities. It is therefore believed that this study would significantly contribute to the global green building body of knowledge.

2. Research framework and hypotheses development

2.1. Research framework

Research framework is useful for developing new knowledge (Agherdien, 2007) and could be based upon theory and/or logic (Simon and Goes, 2011). The framework used for this study has a theoretical basis. Aktas and Ozorhon (2015) observed that previous green building-related studies had not developed frameworks for analyzing the green building adoption process. As a result, drawing on existing frameworks for analyzing the general innovation process within the construction industry, they developed a framework to analyze the green building adoption process. It was reasonable to do so since green building has been considered an innovation in the construction industry (Yudelson, 2007; Potbhare et al., 2009). Aktas and Ozorhon's (2015) framework highlights drivers, barriers, enablers, benefits, resources, and impacts as key issues associated with the green building adoption process. And it aims at allowing a comprehensive analysis to attain a deeper understanding of the whole green building adoption process. Based on Aktas and Ozorhon's (2015) framework, a framework (Fig. 1) is proposed for guiding the investigation of the influences of barriers, drivers, and promotion strategies on GBTs adoption in the present study. The proposed framework should be more useful for gaining a better understanding of the myriad issues associated with GBTs adoption than analyzing the issues separately in separate research papers. Inside this proposed framework, whereas barriers represent the problems that prevent stakeholders from adopting GBTs, drivers and promotion strategies motivate stakeholders to adopt GBTs; drivers represent the benefits of GBTs adoption, and promotion strategies represent factors such as government regulations and incentives. Therefore, similar to Aktas and Ozorhon (2015), while barriers are assigned negative sign (–) in the proposed framework, drivers and promotion strategies are assigned positive sign (+). This informs the directions of the research hypotheses, and what it means is that the drivers and promotion strategies work together against the barriers. These three issues collectively influence the decision to adopt GBTs, therefore it is more appropriate to analyze them simultaneously.

Fig. 1. Research framework.

2.2. Hypotheses development

This research focuses on three broad issues – barriers, drivers, and promotion strategies – and examines how they influence GBTs adoption. GBTs adoption has been widely deemed as vital for enhancing the sustainability of the construction industry (Love et al., 2012; Chan et al., 2017). To promote GBTs adoption and thus improve the sustainability of the construction industry, a large research project was conducted. During the first phases of this research project, Chan et al. (2018) identified a total number of 20 critical barriers to GBTs adoption within the Ghanaian construction industry and categorized them into five constructs – government-related barriers (GRB), human-related barriers (HRB), knowledge and information-related barriers (KIRB), market-related barriers (MRB), and cost and risk-related barriers (CRRB). Since a comprehensive understanding of barriers is necessary for developing appropriate strategies to overcome the barriers and promote the adoption of GBTs, the analysis of barriers is worthwhile. Additionally, Darko et al. (2017c) identified a total number of 16 key drivers for GBTs adoption inside the Ghanaian construction industry and categorized them into five constructs: environment-related drivers (ERD), company-related drivers (CRD), economy and health-related drivers (EHRD), cost and energy-related drivers (CERD), and industry-related drivers (IRD). These drivers, as benefits to be gained from GBTs adoption, when better understood and widely promoted in society, can encourage the adoption of GBTs. Furthermore, Darko and Chan (2018) identified 15 important strategies to promote GBTs adoption in Ghana and categorized them into five constructs: government regulations and standards (GRS), incentives and research and development support (IRDS), awareness and publicity programs (APP), education and information dissemination (EID), and awards and recognition (AR). Identifying and implementing proper promotion strategies could greatly help to promote the more widespread adoption of GBTs.

Table 1 presents the 15 constructs – i.e., the aforesaid constructs for barriers, drivers, and promotion strategies – and their respective measurement items, which are adapted in this study to investigate the influences of barriers, drivers, and promotion strategies on GBTs adoption. That is to say, the present study builds on the studies of Chan et al. (2018), Darko et al. (2017c), and Darko and Chan (2018). GBTs adoption in the present study is measured using six items, which are also presented in Table 1. Firstly, Lam et al. (2009) used some eight items to assess the state of green specifications adoption in Hong Kong. Later, Shi et al. (2013) adapted these items to also assess the state of green construction adoption in China. The measurement items of GBTs adoption were thus developed based on the studies of Lam et al. (2009) and Shi et al. (2013), with some modifications to suit the present study.

Table 1

Constructs and their respective measurement items (Adapted from Chan et al., 2018, Darko et al., 2017c, Darko and Chan, 2018, Lam et al., 2009, and Shi et al., 2013).

Constructs	Code	Measurement items
	Barriers to GBTs adoption	
Government-related barriers (GRB)	GRB1	Lack of government incentives
	GRB2	Lack of green building polices and regulations
	GRB3	Lack of GBTs promotion by government
	GRB4	Lack of local institutes and facilities for GBTs R&D
	GRB5	Lack of green building rating systems and labeling programs
	GRB6	Lack of demonstration projects
	GRB7	Lack of green building technological training for project staff
Human-related barriers (HRB)	HRB1	Resistance to change from the use of traditional technologies
	HRB2	Lack of importance attached to GBTs by senior management
	HRB3	Unfamiliarity of construction professionals with GBTs
	HRB4	Unavailability of GBTs suppliers
	HRB5	Lack of financing schemes (e.g., bank loans)
Knowledge and information-related barriers (KIRB)	KIRB1	Lack of professional knowledge and expertise in GBTs
	KIRB2	Lack of GBTs databases and information
	KIRB3	Lack of awareness of GBTs and their benefits
Market-related barriers (MRB)	MRB1	Unavailability of GBTs in the local market
	MRB2	Lack of interest from clients and market demand
	MRB3	Limited experience with the use of nontraditional procurement methods
Cost and risk-related barriers (CRRB)	CRRB1	Higher costs of GBTs
	CRRB2	Risks and uncertainties involved in adopting new technologies
	Drivers for GBTs adoption	
Environment-related drivers (ERD)	ERD1	Reduced environmental impact
	ERD2	Improved indoor environmental quality
	ERD3	Greater water efficiency
	ERD4	Non-renewable resources conservation
	ERD5	High return on investment
Company-related drivers (CRD)	CRD1	Company image and reputation
	CRD2	Improved occupants' productivity
	CRD3	Better workplace environment
	CRD4	Increased building value
Economy and health-related drivers (EHRD)	EHRD1	Reduced use of construction materials in the economy

	EHRD2	Improved occupants' health and well-being
	EHRD3	Job creation opportunity
Cost and energy-related drivers (CERD)	CERD1	Reduced whole lifecycle costs
	CERD2	Greater energy efficiency
Industry-related drivers (IRD)	IRD1	Setting a standard for future design and construction
	IRD2	Facilitating a culture of best practice sharing
Promotion strategies for GBTs adoption		
Government regulations and standards (GRS)	GRS1	Mandatory green building policies and regulations
	GRS2	Green rating and labeling programs
	GRS3	Better enforcement of green building policies after they have been developed
	GRS4	Availability of competent and proactive GBTs promotion teams and local authorities
Incentives and R&D support (IRDS)	IRDS1	Financial and further market-based incentives for GBTs adoption
	IRDS2	A strengthened GBTs R&D
	IRDS3	Low-interest loans and subsidies from government and financial institutions
Awareness and publicity programs (APP)	APP1	Public environmental awareness creation through workshops, seminars, and conferences
	APP2	More publicity through media (e.g., print media, radio, television, and internet)
	APP3	Support from executive management
Education and information dissemination (EID)	EID1	GBTs-related educational and training programs for developers, contractors, and policy makers
	EID2	Availability of better information on cost and benefits of GBTs
	EID3	Availability of institutional framework for effective GBTs implementation
Awards and recognition (AR)	AR1	Acknowledging and rewarding GBTs adopters publicly
	AR2	More GBTs adoption advocacy by the Ghana Environmental Protection Agency
GBTs adoption		
GBTs adoption (GA)	GA1	Specifications should consider GBTs
	GA2	Current construction has not sufficiently considered GBTs
	GA3	GBTs information and databases are not adequately available in your company
	GA4	Our senior management is willing to support GBTs adoption
	GA5	GBTs adoption should be forced by government
	GA6	Guides for implementing GBTs cannot be easily found in Ghana

Note: R&D = Research and development.

Comprehensive literature reviews regarding the barriers, drivers, and promotion strategies of GBTs and practices adoption are presented by Chan et al. (2018), Darko et al. (2017c), and Darko and Chan (2018), respectively. In addition, Darko and Chan (2017) and Darko et al. (2017b), respectively, published comprehensive literature review studies regarding the barriers and drivers of GBTs and practices adoption. Insights from the literatures generally suggest that barriers can make it difficult for stakeholders to adopt GBTs; that is, barriers have a potentially negative influence on GBTs adoption. On the other hand, drivers and promotion strategies have been argued to drive stakeholders to adopt GBTs; that is, drivers and promotion strategies have a potentially positive influence on GBTs adoption. In the light of these insights and the research framework (Fig. 1), the following research hypotheses are proposed:

H1a: Government-related barriers have a negative influence on GBTs adoption.

H1b: Human-related barriers have a negative influence on GBTs adoption.

H1c: Knowledge and information-related barriers have a negative influence on GBTs adoption.

H1d: Market-related barriers have a negative influence on GBTs adoption.

H1e: Cost and risk-related barriers have a negative influence on GBTs adoption.

H2a: Environment-related drivers have a positive influence on GBTs adoption.

H2b: Company-related drivers have a positive influence on GBTs adoption.

H2c: Economy and health-related drivers have a positive influence on GBTs adoption.

H2d: Cost and energy-related drivers have a positive influence on GBTs adoption.

H2e: Industry-related drivers have a positive influence on GBTs adoption.

H3a: Government regulations and standards would have a positive influence on GBTs adoption.

H3b: Incentives and R&D support would have a positive influence on GBTs adoption.

H3c: Awareness and publicity programs would have a positive influence on GBTs adoption.

H3d: Education and information dissemination would have a positive influence on GBTs adoption.

H3e: Awards and recognition would have a positive influence on GBTs adoption.

The hypothetical model is presented in Fig. 2. The hypotheses are tested in this study, and the results contribute to deepening the understanding of the roles of different factors in hindering or fostering the adoption of GBTs. Such an understanding is crucial to help policy makers and stakeholders formulate and implement appropriate policies and strategies to advance the GBTs adoption.

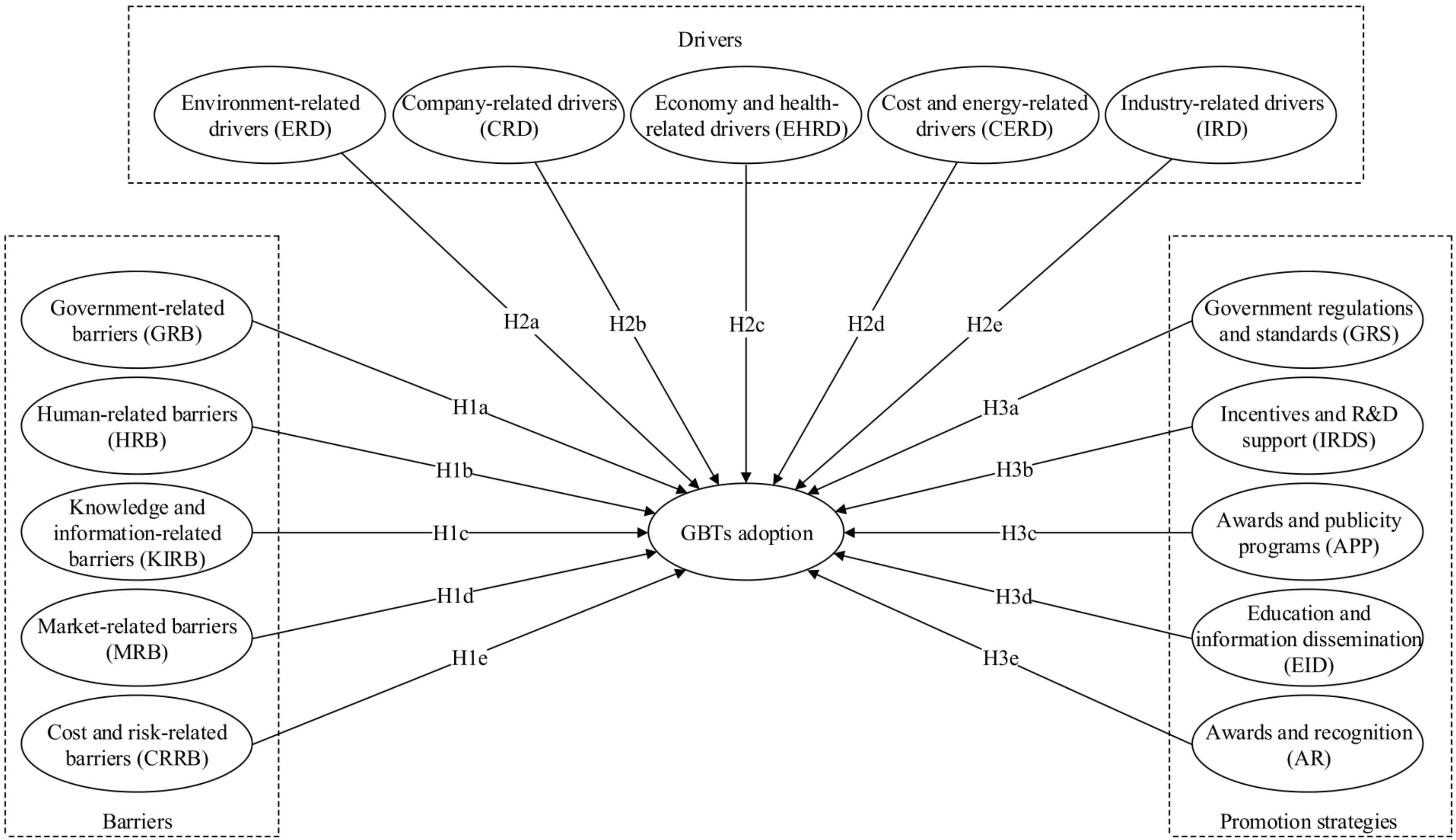


Fig. 2. Hypothetical model of the barriers, drivers, and promotion strategies influencing GBTs adoption.

3. Research methodology

3.1. Data collection

As a systematic approach to data collection based on a sample, the method of questionnaire survey has seen wide usage in green building research (Zhao et al., 2016; Hwang et al., 2017). Besides, the questionnaire survey method is an effective method to achieve "quantifiability and objectiveness" (Ackroyd and Hughes, 1981). For these reasons, in order to investigate the influences of barriers, drivers, and promotion strategies on GBTs adoption, a questionnaire survey was carried out. The survey questionnaire contained six sections. The first section explained the research objective and presented contact details. The second section was designed to gather background information of the respondents, including their company types, professions, industrial experience, and green building experience. Within the third section, the respondents were asked to assess the measurement items of GBTs adoption. Within the fourth section, the respondents were asked to rate the measurement items of GBTs adoption barriers. Within the fifth section, the respondents were asked to assess the measurement items of GBTs adoption drivers. Finally, within the sixth section, the respondents were requested to assess the measurement items of GBTs adoption promotion strategies. All of the assessments were made using five-point Likert scales. Table 2 shows the various five-point Likert scales adopted in the survey questionnaire for specific questions. This research applied the five-point Likert scales in accordance with the "seven plus or minus two" principle proposed by Miller (1956), which made it easy for the respondents to express their views. Additionally, the five-point Likert scale has been widely recommended (Ekanayake and Ofori, 2004; Zhang et al., 2011) because of its advantage to yield unambiguous results.

Table 2
Five-point Likert scales used in the survey questionnaire.

Assessment scores	Linguistic terms		
1	Strongly disagree[a]	Not critical[b]	Not important[c]
2	Disagree[a]	Less critical[b]	Less important[c]
3	Neutral[a]	Neutral[b]	Neutral[c]
4	Agree[a]	Critical[b]	Important[c]

5	Strongly agree[a]	Very critical[b]	Very important[c]

Note: [a] The five-point Likert scale applied within the third and fifth sections of the survey questionnaire;
[b] The five-point Likert scale applied within the fourth section of the survey questionnaire;
[c] The five-point Likert scale applied within the sixth section of the survey questionnaire.

The population comprised all industry practitioners with knowledge and understanding of GBTs adoption in Ghana. Since there was no sampling frame for this study, the sample was a nonprobability sample (Zhao et al., 2014). The nonprobability sampling technique can be used to achieve a representative sample (Patton, 2001). It is appropriate when a random sampling method cannot be used to select respondents from the population, but the respondents can rather be selected based on their willingness to participate in the research study (Wilkins, 2011). Thus, a snowball sampling method was used in this study to attain a valid and effective overall sample size. This method was also used in previous construction engineering and management studies (Zhang et al., 2011; Mao et al., 2015), and it allows the gathering and sharing of information and respondents through referral or social networks. Local companies that have been directly involved in the development of green building projects in Ghana were approached to identify the initial respondents. Within the Ghanaian context, this study defines green building projects as building projects that have either obtained the Green Star of South Africa certification or the Leadership in Energy and Environmental Design of the US certification. Currently, these are the two main green building certification systems applied in Ghana (Darko et al., 2017c). The initially identified respondents were asked to share information regarding other knowledgeable participants. Using this approach, 96 questionnaires were distributed to collect responses from contractor, consultant, and developer companies. Eventually, 43 completed questionnaires with valid answers were returned, corresponding to a 44.8% response rate. This sample size satisfied the recommendation that a sample size should be above 30 for the central limit theorem to hold true (Ott and Longnecker, 2010). Also, because GBTs have not been widely adopted within the Ghanaian construction industry, the number of experienced professionals is limited.

Furthermore, the sample size was high compared with the earlier green building studies that used sample sizes of 31 (Zhao et al., 2016) and 39 (Shen et al., 2017a).

The background information of the respondents is shown in Table 3. With company types, 37, 33, and 30% of the respondents were from consultant, contractor, and developer companies, respectively. In terms of professions, engineers (30%) formed the majority of the respondents, followed by quantity surveyors (26%), and architects (21%) and project managers (21%). With regard to the working experience of the respondents in the construction industry, the major portion (86%) of the respondents had more than 5 years' working experience; only 14% had 1-5 years' working experience. Moreover, all the respondents had experience in green building, with 56% having 1-3 years' experience, 25% having 4-6 years' experience, and 19% having over 6 years' experience. In light of the few green building projects launched in Ghana in recent years, this result could be deemed reasonable. The respondents' industrial and green building experience helped to ensure and enhance the reliability of the research findings.

Table 3
Background information of the respondents.

Characteristics	Frequency	Percentage
Company types		
Consultant	16	37
Contractor	14	33
Developer	13	30
Professions		
Engineer	13	30
Quantity surveyor	11	26
Architect	9	21
Project manager	9	21
Contracts manager	1	2
Years of working experience in the construction industry		
1-5 years	6	14
6-10 years	17	40
11-15 years	10	23
16-20 years	3	7
> 20 years	7	16
Years of experience in green building		
1-3 years	24	56
4-6 years	11	25
> 6 years	8	19

3.2. Data analysis

In order to test the hypotheses, SEM, which is a multivariate statistical analysis technique, was conducted. SEM involves two kinds of variables, namely observable variables and latent variables. Whereas the observable variables (hereafter referred to as measurement items) are variables that can be directly measured, the latent variables (hereafter referred to as constructs) are variables that cannot be directly measured and therefore are inferred from the measurement items. SEM not only tests hypotheses among measurement items and constructs, but it also employs a confirmatory approach to evaluate a structural hypothetical model based upon a phenomenon (Byrne, 2013). In other words, SEM evaluates direct and indirect relationships among one or several independent variables and one or several dependent variables. Due to the fact that SEM goes beyond the traditional multiple regression analysis, analysis of variance, and factor analysis (Ozorhon and Oral, 2017), SEM was selected as the method of analysis in this research. Moreover, different from the multivariate regression analysis and factor analysis, SEM has the ability to conduct both confirmatory factor analysis (CFA) and path analysis at the same time within a single structural equation model (Lim et al., 2012; Xiong et al., 2015). A typical structural equation model consists of a set of measurement models and a structural model. While a measurement model evaluates the relationships among a construct and the measurement items within the domain of the construct, a structural model displays the relationships among constructs (Hair et al., 2014a).

There are two approaches to SEM, the covariance-based SEM (CB-SEM) approach and the variance-based PLS-SEM approach. Unlike CB-SEM, PLS-SEM can handle small sample sizes and nonnormal data (Hair et al., 2014a, b). This advantage over CB-SEM has made PLS-SEM popular in construction engineering and management research of late. For example, with a sample size of 35 professionals, Zhao and Singhaputtangkul (2016) used PLS-SEM to investigate the impacts of firm characteristics on enterprise risk management within Chinese construction firms; and Aibinu et al. (2011) utilized PLS-SEM to examine the relation between cooperative behavior and organizational justice in construction, with a sample of 41 contractors. Thus, similarly, the present study adopted PLS-SEM, using SmartPLS 3.2.7 software, to test the research hypotheses and validate the hypothetical models.

CFA can test the relationships among measurement items and their construct (Zhao et al., 2014). In this research, the measurement items and the constructs used inside the measurement and structural models, respectively, are presented in Table 1. According to Hair et al. (2014a), after specifying the measurement and structural models, the reliability and validity of the measurement items within the measurement models ought to be evaluated. Evaluating the measurement models is vital because it helps to ensure that the constructs, which form the basis for evaluating the relationships hypothesized in the structural model, are accurately represented and measured, thereby verifying the adequacy of the measurement models for the path analysis.

Reliability refers to the extent to which measurement of constructs with multi-item scale reflects the accurate scores of the constructs relative to the error (Hulland, 1999). Composite reliability score and Cronbach's alpha coefficient were used to assess the internal consistency reliability of the measurement items representing and measuring each construct. In this respect, while composite reliability score and Cronbach's alpha coefficient are similar and have the same interpretation (Aibinu and Al-Lawati, 2010), composite reliability scores should be above 0.70 (Hair et al., 1998) and Cronbach's alpha coefficients should be 0.70 or higher (Nunnally, 1978). Once reliability has been assessed, validity, which includes convergent validity and discriminant validity of the constructs, must be assessed. Factor loadings represent the bivariate correlations between measurement items and their corresponding construct and are the means through which the measurement items are linked to the construct (Hair et al., 2014a). For a satisfactory level of convergent validity, each measurement item needs to have a factor loading of 0.50 or higher (Hulland, 1999) and the average variance extracted (AVE) of each construct should also be 0.50 or higher (Fornell and Larcker, 1981). AVE can be simply defined as the grand mean value of the squared loadings of a set of measurement items and is equivalent to a construct's communality (Hair et al., 2014a, b). Discriminant validity tests whether a construct measures what it is originally intended to measure; simply put, discriminant validity tests the extent to which a construct is different from other constructs. To assess discriminant validity, two techniques were used. First, Fornell and Larcker (1981) criterion, which states that the variance that a construct shares with its measurement items is higher than what it shares with any other construct, was used. In this respect, each construct's AVE should be more than the highest squared correlation with any other construct. Second, examination of the cross loadings of the measurement items was conducted to verify discriminant validity. In this respect, each measurement item's loading on its respective construct must be greater than the cross loadings on other constructs (Chin, 1998).

Path coefficients represent the hypothesized relationships linking constructs (Hair et al., 2014a). After verifying the reliability and validity of the measurement models, the significance of path coefficients must be estimated in order to test the hypotheses inside the structural model. To this end, the bootstrapping technique (Davison and Hinkley, 1997; Helm et al., 2009) was used. Bootstrapping is a versatile technique useful for estimating the distribution of any statistic for any kind of distribution (Jack et al., 2001). Following Hair et al.'s (2014b) recommendation, in this research, the number of bootstrap subsamples was 5,000, and the number of cases was equal to the number of responses (i.e., 43). Using such a large number of bootstrap subsamples is essential to ensure stability of the results. The critical *t*-values for a two-tailed test were 1.65 (significance level = 10%), 1.96 (significance level = 5%) and 2.58 (significance level = 1%) (Hair et al., 2014b). The analysis results are presented and discussed in the following sections.

4. Results

4.1. Barriers

4.1.1. Evaluation of measurement models

Tables 4-6 show the evaluation results of the measurement models in the model of barriers influencing GBTs adoption (Fig. 3). As the CFA factor loading of the measurement item MRB2 was lower than 0.50, it was deleted from the list of measurement items (Table 4). It should be noted that after the deletion of any measurement item that required deletion, the analysis was rerun; this procedure was repeated until reliable and valid measurement models were achieved. This study involves only reflective measurement items because the constructs cause the items; that is, the arrows in Figs. 3-5 point from the constructs to the measurement items. Hair et al. (2014a) stated that reflective measurement items are extremely correlated, interchangeable, and some can be omitted without changing the meaning of the construct. Besides, Nunnally (1978) argued that measurement items with low loadings can be dropped because their contribution to the explanatory power of the model would be insignificant, thus biasing the estimations of other measurement items.

Table 4

Measurement model evaluation (for barriers model).

Construct	Measurement item code	Factor loading	Cronbach's alpha	Composite reliability	AVE
GRB	GRB1	0.647	0.841	0.872	0.551
	GRB2	0.788	–	–	–
	GRB3	0.780	–	–	–
	GRB4	0.738	–	–	–
	GRB5	0.828	–	–	–
	GRB6	0.677	–	–	–
	GRB7	0.634	–	–	–
HRB	HRB1	0.678	0.776	0.782	0.539
	HRB2	0.574	–	–	–
	HRB3	0.974	–	–	–
	HRB4	0.510	–	–	–
	HRB5	0.714	–	–	–
KIRB	KIRB1	0.875	0.822	0.894	0.734
	KIRB2	0.893	–	–	–
	KIRB3	0.805	–	–	–
MRB	MRB1	0.628	0.744	0.771	0.569
	MRB3	0.994	–	–	–
CRRB	CRRB1	0.860	0.786	0.792	0.576
	CRRB2	0.642	–	–	–
GA	GA1	0.675	0.737	0.763	0.616
	GA2	0.718	–	–	–
	GA3	0.617	–	–	–
	GA4	0.709	–	–	–
	GA5	0.597	–	–	–
	GA6	0.684	–	–	–

Note: The measurement item MRB2 was removed from the initial model because its factor loading (0.387) was below 0.50; GRB = Government-related barriers; HRB = Human-related barriers; KIRB = Knowledge and information-related barriers; MRB = Market-related barriers; CRRB = Cost and risk-related barriers; GA = GBTs adoption; AVE = Average variance extracted.

Table 5

Discriminant validity of constructs (for barriers model).

Construct	GRB	HRB	KIRB	MRB	CRRB	GA
GRB	**0.708**	–	–	–	–	–
HRB	0.439	**0.662**	–	–	–	–
KIRB	0.430	0.361	**0.859**	–	–	–
MRB	0.379	0.201	0.274	**0.754**	–	–
CRRB	0.082	0.075	0.014	0.075	**0.759**	–
GA	0.558	0.225	0.326	0.427	0.233	**0.563**

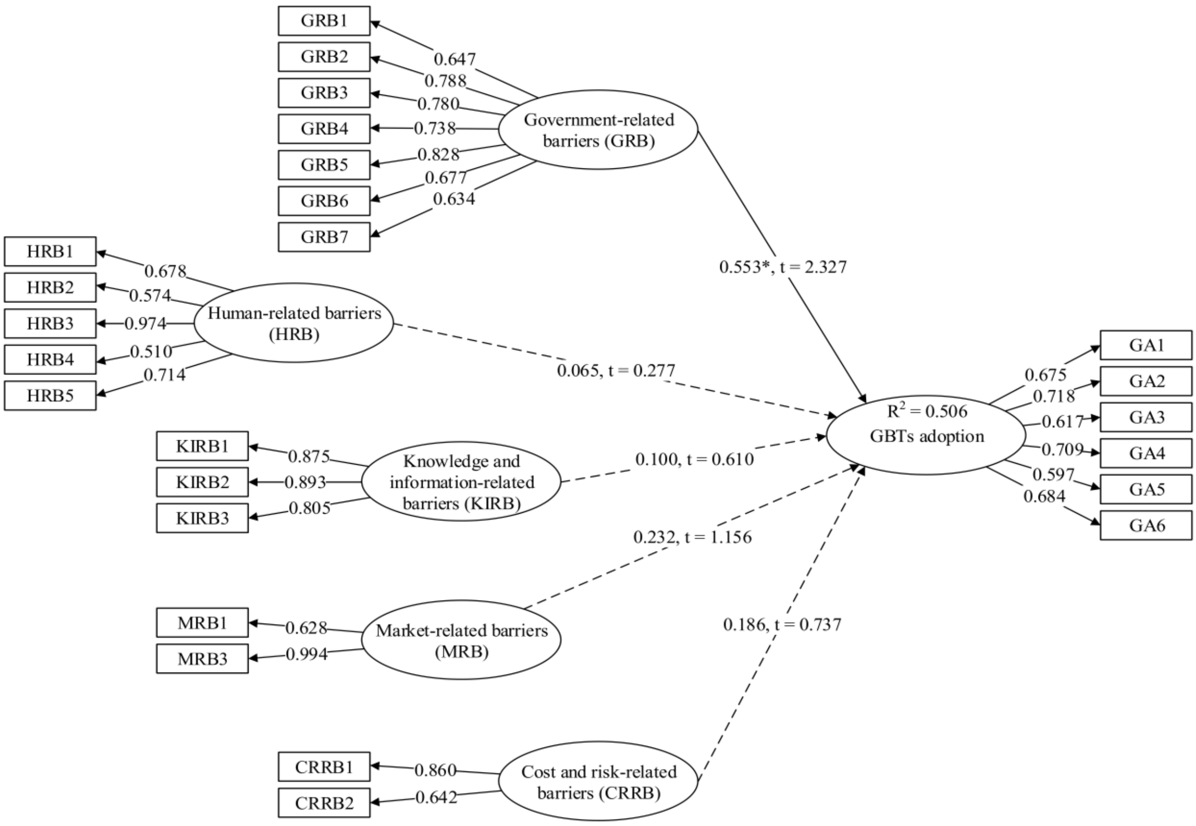
Note: The bold diagonal values are the square root of average variance extracted of each construct, while the other values are the correlations amongst constructs; GRB = Government-related barriers; HRB = Human-related barriers; KIRB = Knowledge and information-related barriers; MRB = Market-related barriers; CRRB = Cost and risk-related barriers; GA = GBTs adoption.

Table 6

Cross loadings of measurement items (for barriers model).

Measurement item code	GRB	HRB	KIRB	MRB	CRRB	GA
GRB1	**0.647**	0.325	0.298	0.383	0.084	0.402
GRB2	**0.788**	0.204	0.187	0.237	0.244	0.309
GRB3	**0.780**	0.470	0.326	0.256	0.107	0.468
GRB4	**0.738**	0.181	0.370	0.223	0.036	0.402
GRB5	**0.828**	0.378	0.267	0.258	0.144	0.425
GRB6	**0.677**	0.368	0.441	0.333	0.144	0.380
GRB7	**0.634**	0.269	0.154	0.160	0.039	0.084
HRB1	0.264	**0.678**	0.045	0.131	0.161	0.056
HRB2	0.209	**0.574**	0.058	0.176	0.077	0.016
HRB3	0.456	**0.974**	0.398	0.200	0.072	0.251
HRB4	0.166	**0.510**	0.200	0.178	0.116	0.033
HRB5	0.342	**0.714**	0.437	0.330	0.027	0.017
KIRB1	0.310	0.315	**0.875**	0.280	0.041	0.232
KIRB2	0.375	0.243	**0.893**	0.257	0.130	0.322
KIRB3	0.413	0.384	**0.805**	0.170	0.082	0.272
MRB1	0.250	0.146	0.177	**0.628**	0.387	0.051
MRB3	0.365	0.192	0.305	**0.994**	0.080	0.438
CRRB1	0.059	0.056	0.031	0.112	**0.860**	0.208
CRRB2	0.069	0.231	0.020	0.022	**0.642**	0.138
GA1	0.356	0.180	0.041	0.266	0.250	**0.675**
GA2	0.291	0.203	0.051	0.137	0.060	**0.718**
GA3	0.052	0.032	0.245	0.376	0.018	**0.617**
GA4	0.382	0.181	0.376	0.356	0.201	**0.709**
GA5	0.221	0.081	0.188	0.286	0.017	**0.597**
GA6	0.455	0.093	0.160	0.054	0.128	**0.684**

Note: Bold values show that each measurement item had the highest loading on its respective construct; GRB = Government-related barriers; HRB = Human-related barriers; KIRB = Knowledge and information-related barriers; MRB = Market-related barriers; CRRB = Cost and risk-related barriers; GA = GBTs adoption.



Note: * Indicates level of significance at $p < 0.05$;
► Indicates a significant path (hypothesis supported);
► Indicates an insignificant path (hypothesis not supported).

Fig. 3. Final structural equation model of barriers influencing GBTs adoption.

As Table 4 shows, all Cronbach's alpha coefficients and composite reliability scores were above 0.70, indicating an acceptable level of internal consistency reliability of the measurement items. In addition, all factor loadings and AVEs were above 0.50, which provides evidence of convergent validity of the constructs. An AVE above 0.50 indicates that the construct explains more than 50% of the variance in its measurement items, which is satisfactory. Moreover, as shown in Table 5, no correlation amongst any two constructs exceeded the square roots of their AVEs, providing the first evidence of discriminant validity of the constructs. Further evidence of discriminant validity is provided by examining the cross loadings of the measurement items. Table 6 shows that there is no cross-loading problem, as each measurement item had the highest loading on its corresponding construct. These results show that the measurement models were reliable and valid for the structural path modeling.

4.1.2. Evaluation of structural model

Table 7 shows the bootstrapping results for the barriers model. The results show that the path linking government-related barriers to GBTs adoption had a *t*-value greater than 1.96, implying that it was statistically significant at the 0.05 level. Therefore, hypothesis H1a was supported. Path coefficients are equivalents of regression weights (Ozorhon and Oral, 2017). The higher the path coefficient, the stronger the influence of an independent variable on the dependent variable (Aibinu and Al-Lawati, 2010). As Murari (2015) advised, a path coefficient ranging from 0.1 to 0.3 indicates a weak influence, 0.3 to 0.5 indicates a moderate influence, and 0.5 to 1.0 indicates a strong influence. In this research, hypothesis H1a, which is the only supported hypothesis in the barriers model, had a path coefficient of 0.553, indicating a strong influence. In contrast, the results did not provide support for hypotheses H1b, H1c, H1d, and H1e; these hypotheses had low path coefficients with *t*-values below 1.65, 1.96, or 2.58. These results show that the influences of human-related barriers, knowledge and information-related barriers, market-related barriers, and cost and risk-related barriers on GBTs adoption were not significant. The final structural equation model depicting the influence of each barrier on GBTs adoption is illustrated in Fig. 3. The coefficient of determination (R^2) of the dependent variable, GBTs adoption, was 0.506, indicating a satisfactory level of predictive accuracy and therefore quality of the model (Hair et al., 2014a).

Table 7
Structural model evaluation (for barriers model).

Hypothetical path	Path coefficient	*t*-Value	*p*-Value	Interpretation
H1a: GRB → GA	0.553	2.327	0.020*	Supported
H1b: HRB → GA	0.065	0.277	0.782	Not supported
H1c: KIRB → GA	0.100	0.610	0.542	Not supported
H1d: MRB → GA	0.232	1.156	0.248	Not supported
H1e: CRRB → GA	0.186	0.737	0.461	Not supported

Note: * The path coefficient is significant at $p < 0.05$; GRB = Government-related barriers; HRB = Human-related barriers; KIRB = Knowledge and information-related barriers; MRB = Market-related barriers; CRRB = Cost and risk-related barriers; GA = GBTs adoption.

4.2. Drivers

4.2.1. Evaluation of measurement models

Tables 8-10 show the evaluation results of the measurement models in the model of drivers influencing GBTs adoption (Fig. 4). As the CFA factor loadings of the measurement items GA2, GA4, and GA6 were lower than 0.50, they were deleted from the list of measurement items (Table 8). Also, it could be noted from the results in Table 8 that the construct GA had a Cronbach's alpha coefficient lower than 0.70; however, since its composite reliability score was above 0.70, it is still considered that its measurement items have an acceptable level of internal consistency reliability. This is because composite reliability provides a more proper measure of internal consistency reliability than Cronbach's alpha (Fornell and Larcker, 1981; Hair et al., 2014a) for certain reasons. For example, composite reliability does not assume that all measurement items have equal loadings as Cronbach's alpha does (Hair et al., 2014a). Also, Cronbach's alpha is sensitive to the number of measurement items within the scale and usually underestimates internal consistency reliability, whereas composite reliability aids PLS-SEM to accommodate different measurement item reliabilities and avoid the underestimation related to Cronbach's alpha (Hair et al., 2014a).

Apart from the two observations above, the interpretation of the results of the measurement models herein (Tables 8-10) is the same as the interpretation of results in section 4.1.1.

Table 8
Measurement model evaluation (for drivers model).

Construct	Measurement item code	Factor loading	Cronbach's alpha	Composite reliability	AVE
ERD	ERD1	0.756	0.814	0.856	0.553
	ERD2	0.789	–	–	–
	ERD3	0.808	–	–	–
	ERD4	0.533	–	–	–
	ERD5	0.854	–	–	–
CRD	CRD1	0.725	0.768	0.848	0.584
	CRD2	0.752	–	–	–
	CRD3	0.728	–	–	–
	CRD4	0.846	–	–	–
EHRD	EHRD1	0.757	0.745	0.849	0.653
	EHRD2	0.836	–	–	–
	EHRD3	0.829	–	–	–
CERD	CERD1	0.893	0.737	0.884	0.792
	CERD2	0.886	–	–	–
IRD	IRD1	0.954	0.744	0.876	0.781
	IRD2	0.807	–	–	–
GA	GA1	0.859	0.624	0.795	0.583
	GA3	0.546	–	–	–
	GA5	0.901	–	–	–

Note: The measurement items GA2, GA4, and GA6 were removed from the initial model because their factor loadings (0.344, 0.417, and 0.033, respectively) were below 0.50; ERD = Environment-related drivers; CRD = Company-related drivers; EHRD = Economy and health-related drivers; CERD = Cost and energy-related drivers; IRD = Industry-related drivers; GA = GBTs adoption; AVE = Average variance extracted.

Table 9

Discriminant validity of constructs (for drivers model).

Construct	ERD	CRD	EHRD	CERD	IRD	GA
ERD	**0.743**	–	–	–	–	–
CRD	0.628	**0.764**	–	–	–	–
EHRD	0.535	0.548	**0.808**	–	–	–
CERD	0.397	0.366	0.348	**0.890**	–	–
IRD	0.351	0.426	0.380	0.355	**0.884**	–
GA	0.331	0.710	0.394	0.452	0.453	**0.763**

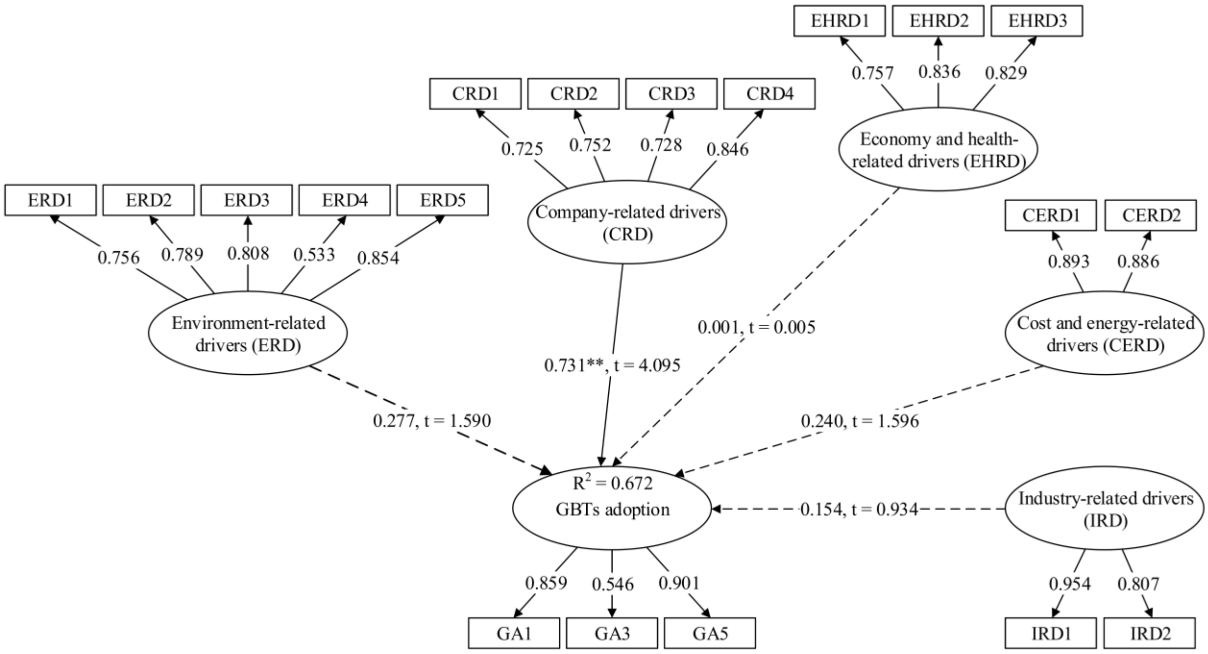
Note: The bold diagonal values are the square root of average variance extracted of each construct, while the other values are the correlations amongst constructs; ERD = Environment-related drivers; CRD = Company-related drivers; EHRD = Economy and health-related drivers; CERD = Cost and energy-related drivers; IRD = Industry-related drivers; GA = GBTs adoption.

Table 10

Cross loadings of measurement items (for drivers model).

Measurement item code	ERD	CRD	EHRD	CERD	IRD	GA
ERD1	**0.756**	0.279	0.295	0.171	0.224	0.150
ERD2	**0.789**	0.512	0.326	0.375	0.364	0.206
ERD3	**0.808**	0.405	0.502	0.511	0.355	0.232
ERD4	**0.533**	0.230	0.359	0.288	0.149	0.021
ERD5	**0.854**	0.669	0.503	0.234	0.227	0.381
CRD1	0.323	**0.725**	0.347	0.210	0.315	0.477
CRD2	0.560	**0.752**	0.545	0.393	0.326	0.426
CRD3	0.700	**0.728**	0.536	0.291	0.306	0.438
CRD4	0.421	**0.846**	0.338	0.262	0.355	0.736
EHRD1	0.402	0.308	**0.757**	0.168	0.188	0.396
EHRD2	0.591	0.447	**0.836**	0.391	0.341	0.363
EHRD3	0.297	0.522	**0.829**	0.237	0.232	0.351
CERD1	0.377	0.342	0.372	**0.893**	0.249	0.408
CERD2	0.328	0.308	0.246	**0.886**	0.384	0.396
IRD1	0.301	0.389	0.374	0.372	**0.954**	0.491
IRD2	0.350	0.378	0.284	0.221	**0.807**	0.250
GA1	0.265	0.613	0.304	0.331	0.373	**0.859**
GA3	0.189	0.295	0.107	0.214	0.070	**0.546**
GA5	0.300	0.647	0.412	0.453	0.475	**0.901**

Note: Bold values show that each measurement item had the highest loading on its respective construct; ERD = Environment-related drivers; CRD = Company-related drivers; EHRD = Economy and health-related drivers; CERD = Cost and energy-related drivers; IRD = Industry-related drivers; GA = GBTs adoption.



Note: ** Indicates level of significance at $p < 0.01$;
Indicates a significant path (hypothesis supported);
Indicates an insignificant path (hypothesis not supported).

Fig. 4. Final structural equation model of drivers influencing GBTs adoption.

4.2.2. Evaluation of structural model

Table 11 shows the bootstrapping results for the drivers models. The results show that the path linking company-related drivers to GBTs adoption had a *t*-value greater than 2.58, implying that it was statistically significant at the 0.01 level. Therefore, hypothesis H2b was supported; this is the only supported hypothesis within the drivers model and it had a path coefficient of 0.731, indicating a strong influence. On the other hand, the results did not provide support for hypotheses H2a, H2c, H2d, and H2e; these hypotheses had low path coefficients with *t*-values below 1.65, 1.96, or 2.58. These results show that the influences of environment-related drivers, economy and health-related drivers, cost and energy-related drivers, and industry-related drivers on GBTs adoption were not significant. The final structural equation model depicting the influence of each driver on GBTs adoption is illustrated in Fig. 4. The R^2 of GBTs adoption was 0.672, indicating a satisfactory level of predictive accuracy and hence quality of the model (Hair et al., 2014a).

Table 11

Structural model evaluation (for drivers model).

Hypothetical path	Path coefficient	*t*-Value	*p*-Value	Interpretation
H2a: ERD → GA	0.277	1.590	0.112	Not supported
H2b: CRD → GA	0.731	4.095	0.000**	Supported
H2c: EHRD → GA	0.001	0.005	0.996	Not supported
H2d: CERD → GA	0.240	1.596	0.110	Not supported
H2e: IRD → GA	0.154	0.934	0.350	Not supported

Note: ** The path coefficient is significant at $p < 0.01$; ERD = Environment-related drivers; CRD = Company-related drivers; EHRD = Economy and health-related drivers; CERD = Cost and energy-related drivers; IRD = Industry-related drivers; GA = GBTs adoption.

4.3. Promotion strategies

4.3.1. Evaluation of measurement models

Tables 12-14 show the evaluation results of the measurement models within the model of promotion strategies influencing GBTs adoption (Fig. 5). As the CFA factor loadings of the measurement items GRS3 and GA6 were lower than 0.50, they were deleted from the list of measurement items (Table 12). Apart from this observation, the interpretation of the results of the measurement models herein (Tables 12-14) is the same as the interpretation of results in section 4.1.1.

Table 12

Measurement model evaluation (for promotion strategies model).

Construct	Measurement item code	Factor loading	Cronbach's alpha	Composite reliability	AVE
GRS	GRS1	0.898	0.814	0.890	0.731
	GRS2	0.925	–	–	–
	GRS4	0.729	–	–	–
IRDS	IRDS1	0.992	0.763	0.767	0.551
	IRDS2	0.508	–	–	–
	IRDS3	0.708	–	–	–
APP	APP1	0.670	0.785	0.830	0.626
	APP2	0.713	–	–	–
	APP3	0.960	–	–	–
EID	EID1	0.866	0.800	0.881	0.712
	EID2	0.785	–	–	–
	EID3	0.877	–	–	–
AR	AR1	0.713	0.802	0.876	0.659
	AR2	0.946	–	–	–
GA	GA1	0.917	0.766	0.895	0.809
	GA2	0.723	–	–	–
	GA3	0.656	–	–	–
	GA4	0.711	–	–	–
	GA5	0.882	–	–	–

Note: The measurement items GRS3 and GA6 were removed from the initial model because their factor loadings (0.408 and 0.321, respectively) were below 0.50; GRS = Government regulations and standards; IRDS = Incentives and R&D support; APP = Awareness and publicity programs; EID = Education and information dissemination; AR = Awards and recognition; GA = GBTs adoption; AVE = Average variance extracted.

Table 13

Discriminant validity of constructs (for promotion strategies model).

Construct	GRS	IRDS	APP	EID	AR	GA
GRS	**0.855**	–	–	–	–	–

IRDS	0.079	**0.742**	–	–	–	–
APP	0.406	0.197	**0.791**	–	–	–
EID	0.476	0.208	0.366	**0.844**	–	–
AR	0.004	0.005	0.195	0.001	**0.836**	–
GA	0.509	0.058	0.216	0.173	0.180	**0.900**

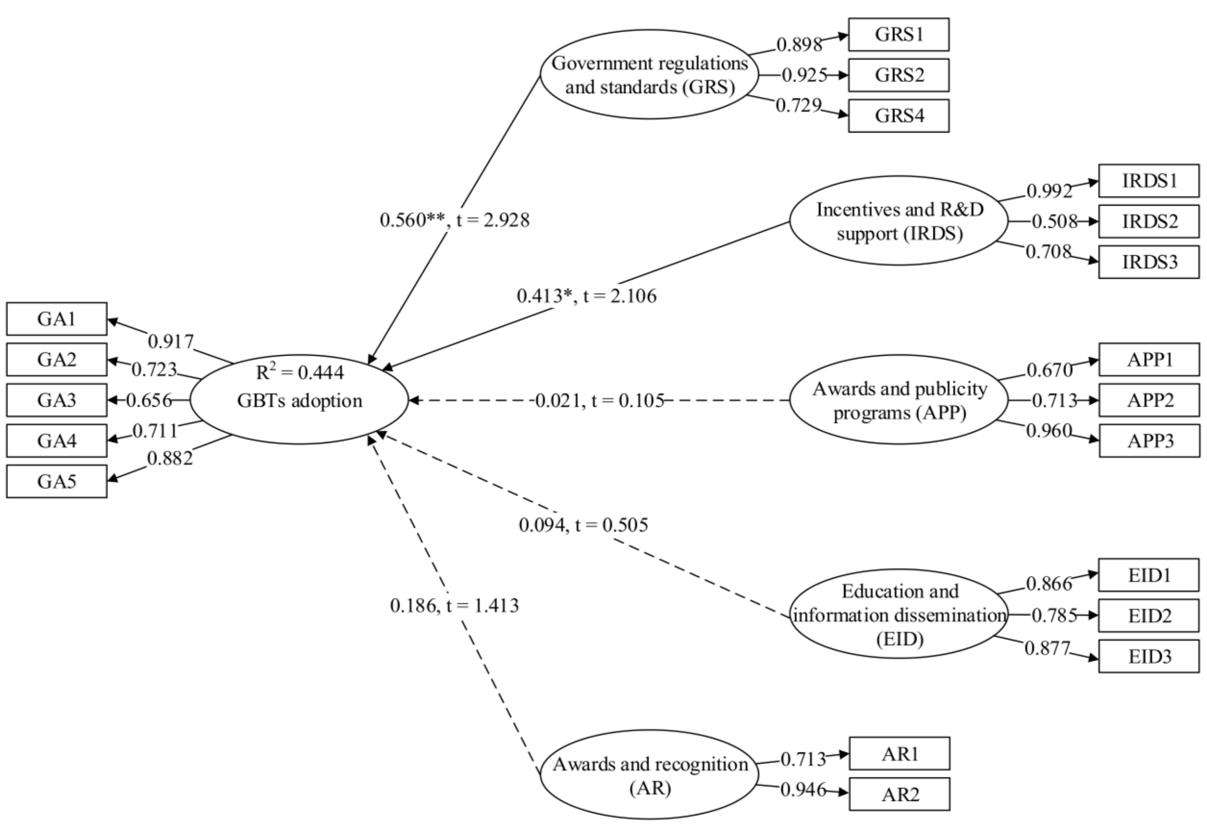
Note: The bold diagonal values are the square root of average variance extracted of each construct, while the other values are the correlations amongst constructs; GRS = Government regulations and standards; IRDS = Incentives and R&D support; APP = Awareness and publicity programs; EID = Education and information dissemination; AR = Awards and recognition; GA = GBTs adoption.

Table 14

Cross loadings of measurement items (for promotion strategies model).

Measurement item code	GRS	IRDS	APP	EID	AR	GA
GRS1	**0.898**	0.103	0.277	0.249	0.011	0.457
GRS2	**0.925**	0.057	0.347	0.472	0.052	0.497
GRS4	**0.729**	0.209	0.458	0.545	0.080	0.334
IRDS1	0.075	**0.992**	0.208	0.206	0.007	0.061
IRDS2	0.271	**0.508**	0.248	0.374	0.090	0.004
IRDS3	0.166	**0.708**	0.136	0.298	0.041	0.012
APP1	0.191	0.224	**0.670**	0.339	0.147	0.061
APP2	0.131	0.193	**0.713**	0.480	0.131	0.057
APP3	0.446	0.154	**0.960**	0.278	0.185	0.249
EID1	0.340	0.056	0.196	**0.866**	0.033	0.176
EID2	0.410	0.261	0.398	**0.785**	0.080	0.130
EID3	0.486	0.260	0.379	**0.877**	0.043	0.119
AR1	0.079	0.337	0.254	0.309	**0.713**	0.084
AR2	0.004	0.005	0.195	0.001	**0.946**	0.180
GA1	0.486	0.061	0.216	0.193	0.232	**0.917**
GA2	0.234	0.432	0.057	0.344	0.212	**0.723**
GA3	0.054	0.287	0.199	0.088	0.391	**0.656**
GA4	0.401	0.263	0.345	0.167	0.072	**0.711**
GA5	0.426	0.186	0.169	0.111	0.079	**0.882**

Note: Bold values show that each measurement item had the highest loading on its respective construct; GRS = Government regulations and standards; IRDS = Incentives and R&D support; APP = Awareness and publicity programs; EID = Education and information dissemination; AR = Awards and recognition; GA = GBTs adoption.



Note: ** Indicates level of significance at $p < 0.01$;
* Indicates level of significance at $p < 0.05$;
——▶ Indicates a significant path (hypothesis supported);
·······▶ Indicates an insignificant path (hypothesis not supported).

Fig. 5. Final structural equation model of promotion strategies influencing GBTs adoption.

4.3.2. Evaluation of structural model

Table 15 shows the bootstrapping results for the promotion strategies model. The results show that the path linking government regulations and standards to GBTs adoption had a *t*-value greater than 2.58, implying that it was statistically significant at the 0.01 level. Thus, hypothesis H3a was supported; this hypothesis had a path coefficient of 0.560, indicating a strong influence. Moreover, the path linking incentives and R&D support to GBTs adoption had a *t*-value greater than 1.96, suggesting that it was statistically significant at the 0.05 level. Hence, hypothesis H3b was supported with a path coefficient of 0.413, indicating that although the influences of both "government regulations and standards" (GRS) and "incentives and R&D support" (IRDS) on GBTs adoption were significant, the influence of GRS was stronger than that of IRDS. As for hypotheses H3c, H3d, and H3e, they had low path coefficients with *t*-values below 1.65, 1.96, or 2.58, indicating that they were not supported. That is to say, the influences of awareness and publicity programs, education and information dissemination, and awards and recognition on GBTs adoption were not significant. The final structural equation model depicting the influence of each promotion strategy on GBTs adoption is illustrated in Fig. 5. The R^2 of GBTs adoption was 0.444, which indicates a satisfactory level of predictive accuracy and hence quality of the model (Hair et al., 2014a).

Table 15
Structural model evaluation (for promotion strategies model).

Hypothetical path	Path coefficient	*t*-Value	*p*-Value	Interpretation
H3a: GRS → GA	0.560	2.928	0.003**	Supported
H3b: IRDS → GA	0.413	2.106	0.032*	Supported
H3c: APP → GA	0.021	0.105	0.917	Not supported
H3d: EID → GA	0.094	0.505	0.614	Not supported
H3e: AR → GA	0.186	1.413	0.158	Not supported

Note: ** The path coefficient is significant at $p < 0.01$; * The path coefficient is significant at $p < 0.05$. GRS = Government regulations and standards; IRDS = Incentives and R&D support; APP = Awareness and publicity programs; EID = Education and information dissemination; AR = Awards and recognition; GA = GBTs adoption.

5. Discussion

In this study, a model was proposed to investigate the influences of various barriers, drivers, and promotion strategies on GBTs adoption within the construction industry. The validity of the model was tested based upon data collected from the developing country of Ghana. This section discusses the results of the PLS-SEM.

5.1. Barriers

The PLS-SEM results supported a significantly negative influence of government-related barriers on GBTs adoption. Further, the results suggest that government-related barriers are the most significant barrier hindering the adoption of GBTs in the Ghanaian construction industry. The result can be interpreted that the higher the government-related barriers, the lower the level of GBTs adoption. The research finding is consistent with Djokoto et al. (2014), who pointed out that the adoption of sustainable construction has been low in Ghana because of the lack of government support. Government-related barriers have been considered major barriers to the adoption of GBTs and practices in various other countries as well. For example, in China, Shen et al. (2017b) identified that lack of incentives from the government is one of the significant barriers encountered in green procurement adoption; while in Singapore, Hwang et al. (2017) found that lack of government support is a top barrier inhibiting green business parks adoption. Government-related barriers in this study (Table 1) refer to issues that fall within the purview of government (Chan et al., 2018) and hence their resolution may, to a large extent, require the government's interventions. Because governmental initiatives, such as green building policies and regulations as well as incentives, that could encourage GBTs adoption among construction stakeholders are currently absent in Ghana (Darko et al., 2017c), GBTs adoption is significantly negatively influenced by government-related barriers (path coefficient of 0.553). The lack of government incentives leads to lack of motivation and better financial foundation for many stakeholders to deal with the high investment that might be required for the adoption of GBTs; the high investment may be in terms of finance, time, and human resource (Zailani et al., 2017). Similarly, lack of green building policies and regulations as well as authoritative rating systems may obstruct GBTs adoption because there would be no regulatory or mandatory requirements from the policy makers for companies and the stakeholders to comply with, and therefore they might not be committed to GBTs adoption. Likewise, successful GBTs adoption and promotion requires increased public awareness of the benefits of GBTs (Sadiq, 2018). Hence, the lack of R&D initiatives to improve the understanding of GBTs and their benefits significantly impedes GBTs adoption. Additionally, both government promotion of GBTs and demonstration projects are vital for increasing the pace of GBTs adoption because they help validate the effectiveness of the GBTs to the general public (Potbhare et al., 2009). As a result, the lack of promotion by government and the lack of demonstration projects hamper GBTs adoption within the industry and the public.

On the contrary, this study found that human-related barriers, knowledge and information-related barriers, market-related barriers, and cost and risk-related barriers are not significantly linked to GBTs adoption. This suggests that these groups of barriers do not significantly affect GBTs adoption within the Ghanaian construction industry. According to Hwang et al. (2017), at the initial stage of GBTs adoption, the government practically holds the leading and central role in promoting GBTs adoption; the government-oriented approaches, such as technical and financial supports, green policies and regulations, and incentives, are critical to attracting the industrial practitioners and stakeholders to adopt GBTs. This could explain why at the present stage of GBTs adoption within Ghana, government-related barriers are the only barrier with a significant negative influence on GBTs adoption. Besides, the research finding that knowledge and information-related barriers do not have a significant influence on GBTs adoption is in line with Zailani et al. (2017), who discovered that information-related barriers do not have a significant influence on product return management adoption, which is a sustainable business practice. Furthermore, lack of importance attached to GBTs by senior management and limited experience with the use of nontraditional procurement methods, for example, which are within the human-related barriers and the market-related barriers, respectively, were found to be insignificant barriers of GBTs adoption in Darko et al.'s (2017a) study as well. Nevertheless, the insignificant influence of cost and risk-related barriers is still an interesting finding of this research, as cost is one of the most cited barriers to adopting GBTs and practices (Dwaikat and Ali, 2016; Darko and Chan, 2017). This finding may be because the respondents believed that promotion strategies such as the government providing relevant incentives can help offset the additional cost involved in adopting GBTs.

5.2. Drivers

The PLS-SEM results revealed that company-related drivers have a significant positive influence on GBTs adoption. The results further suggest that company-related drivers are the governing drivers of GBTs adoption in the Ghanaian construction industry (path coefficient of 0.731). This is in line with the result of Ozorhon and Oral's (2017) study, in which firm-related drivers were found to have a positive influence on driving innovation within the construction industry. This research finding may be because GBTs adoption is a relatively new practice in Ghana and many individuals are still unaware of the individual-level benefits (Darko et al., 2017b) associated with it. In consequence, the companies with experienced professionals who are aware of the benefits that the company can gain by investing in GBTs adoption are leading and driving the GBTs adoption activity. At the company level, there are a number of benefits that can be derived from the adoption of GBTs, including good company image and reputation, improved productivity, better workplace environment, and increased building value. Previous studies stress the importance of these benefits in driving GBTs adoption (Zhang et al., 2011; Darko et al., 2017b). Because company-related drivers could provide sound reasons for GBTs adoption, they should serve as a motivation for GBTs adoption. Corporate social responsibility (CSR) is an indispensable factor for companies to improve their public image and reputation (Zitzler et al., 2000), and GBTs adoption is a useful means for companies to demonstrate their commitment to CSR and environmental sustainability (Zhang et al., 2018). Hence, in order to improve company image and reputation, GBTs adoption is advised. The case studies presented by Zhang et al. (2011) indicated that GBTs adoption helped developer companies to improve their public image and reputation as well as their competitiveness. These benefits significantly drive GBTs adoption because the good public image, for example, allows the company to more easily attract high-income customers. Specifically, the good image allows the company to trade its green buildings at relatively higher prices. Increased building value remains a noteworthy driver as green buildings generally have higher market values than non-green buildings (Chan et al., 2016). Management should be concerned about the productivity of employees. Improved productivity is another key driver and it encourages companies to implement GBTs. Previous studies indicated that adopting GBTs in a company building would result in more productive employees (Issa et al., 2010; Al Horr et al., 2016). In this respect, it has been identified that

GBTs adoption could help to increase the productivity of employees by 6 to 25% (Rocky Mountain Institute, 1998; Paul and Taylor, 2008). These productivity benefits could be linked to the better workplace environment that can be achieved through GBTs adoption. For example, GBTs such as green roof could help to provide better thermal comfort for employees to improve their productivity, which can translate into financial benefits for the company. Hence, improved productivity can greatly drive a company to adopt GBTs. In conclusion, this study suggests that company-related drivers are the major driver of GBTs adoption. When considering GBTs adoption, companies (e.g., developer and construction companies) must not merely consider the possible high investment cost; they must also carefully think about and evaluate the potential benefits. In addition, they must be aware that while some benefits might be short-term, others might be long-term. This could help them sustain their commitment to GBTs adoption.

Conversely, this study found that environment-related drivers, economy and health-related drivers, cost and energy-related drivers, and industry-related drivers are not significantly linked to GBTs adoption. This infers that these driver groups are not leading drivers of GBTs adoption within the Ghanaian construction industry. However, when cost and energy-related drivers, for example, must be analyzed, greater energy efficiency should be highlighted as a critical issue because Ghana has over the last four decades seen several major energy crises (Agyarko, 2013; Gyamfi et al., 2018).

5.3. Promotion strategies

The analysis results infer that government regulations and standards are the most significant strategy to promote GBTs adoption in the developing country of Ghana, followed by incentives and R&D support. This may further explain why government-related barriers were also deemed the most significant barrier that hinders the GBTs adoption because it is rational to assume that government regulations and standards may greatly help overcome government-related barriers such as the lack of green building policies and regulations. This result may also imply that the respondents were consistent in their responses, contributing to the reliability of the results. The results indicated that government regulations and standards would have a significant positive influence on GBTs adoption. While there are several compelling arguments in the literature that support this finding (Wong et al., 2016), quantifying the influence of government regulations and standards on GBTs adoption has been given very little scholarly attention. Mulligan et al. (2014) showed that there is little research on the connection between government regulation and the adoption of GBTs and practices. This study has quantified the influence of government regulations and standards in terms of promoting the adoption of GBTs and found that government regulations and standards would have a strong positive influence (path coefficient of 0.560). Government regulations and standards would have a significant influence on GBTs adoption because they would exert regulatory pressure on companies and stakeholders to adopt GBTs. As evidenced by Shen et al. (2017a), regulatory pressure is the main reason for stakeholders to adopt GBTs and practices. Gou et al. (2013) also showed that the adoption of GBTs and practices is one of the activities within the construction industry that "if you don't legislate, people won't start to do it" (p. 170). The present study implies that with mandatory green building policies and regulations in place, the Ghanaian government could significantly promote the adoption of GBTs. Faced with mandatory requirements from the government, stakeholders would have no other choice than to adopt GBTs in their projects in order to avoid fines and penalties due to noncompliance. However, after creating these policies and regulations, the government should attach great importance to their enforcement. This is because, owing to the lack of enforcement, construction stakeholders in some countries have reported low levels of awareness and usage of many of the green policies and regulations that have been issued and enacted by the policy makers (Mulligan et al., 2014). Therefore, better enforcement of green building policies after they have been developed is essential to promoting

GBTs adoption. Likewise, green building rating systems are among the important strategies to promote the GBTs adoption. This agrees with Li et al. (2017), who stated that the establishment of reliable and effective green building rating systems is highly important to promoting green building. To promote GBTs adoption, green building rating systems need to be developed and implemented. Ghana however, at present, does not have its own green building rating systems and hence applies the US's LEED and the South Africa's Green Star rating systems. Although these international rating systems may be helpful in promoting GBTs adoption in Ghana, it would be more useful to create localized rating systems taking into account local sustainability priorities. In this respect, the government and other relevant stakeholders (e.g., advocates and NGO's) should help the Ghana Green Building Council to create relevant green building rating systems. This might also be a promising area for researchers to explore. Another key promotion strategy is availability of competent and proactive GBTs promotion teams and local authorities. According to DuBose et al. (2007), GBTs adoption stands a higher chance of success if there are strong champions to promote it. The study by Blayse and Manley (2004) also indicated that the presence of strong champions plays a pivotal role in promoting innovations, including green innovation, in the construction industry.

The statistical analysis results also showed that incentives and R&D support would have a significant positive influence on GBTs adoption (path coefficient of 0.413). Several previous studies concur that the strategy of providing green building incentives is extremely important to stimulating the adoption of GBTs and practices (Qian et al., 2016; Shazmin et al., 2016). The research finding is also in parallel with that of Fernández et al., (2018), wherein it was identified that spending on R&D contributes positively to the implementation of sustainable development initiatives. Firstly, as defined by Ozdemir (2000, p.13), an incentive is "something that influences people to act in certain ways". Within the construction industry, green building incentives motivate and compel stakeholders to adopt GBTs in their projects. Generally, there are two main categories of incentives provided by local authorities to promote the adoption of GBTs, which are financial and nonfinancial incentives. While financial incentives aim to offset the extra cost involved in adopting GBTs, nonfinancial incentives provide additional benefits or rights (e.g., technical assistance) to the GBTs adopter. To greatly promote GBTs adoption, the provision of financial incentives, such as direct grants, discounted development application fees, and tax reliefs, is recommended to the government of Ghana. These financial incentives should be provided to stakeholders and firms that support GBTs adoption. Several other countries in the world including the United States, Italy, Spain, Romania, Canada, and Bulgaria (Shazmin et al., 2016) have also adopted financial incentives in promoting GBTs adoption; the Ghanaian government can learn from the experiences of these countries. Also, GBTs adoption would be promoted if the government and financial institutions provide low-interest loans to stakeholders who use GBTs (The State of Michigan, 2010; Shan et al., 2017). For the nonfinancial incentives, the government could adopt the gross floor area concession scheme, for example, which has been widely adopted to promote GBTs adoption in developed countries including Hong Kong and Singapore (Qian et al., 2016). Furthermore, having a strong R&D base in green technology would greatly help promote GBTs adoption as R&D is essential for developing innovative technologies and solutions (Zhang, 2015), and for studying the potential benefits of these innovations. Essentially, the result of this study provides additional support and argument for policy makers to promote GBTs R&D expenditure in both the public and private sectors. The government allocating a certain budget to establish green technology R&D centers and institutes would play an important part in shaping and promoting the adoption of GBTs.

On the other hand, this study found that awareness and publicity programs, education and information dissemination, and awards and recognition are not significantly linked to GBTs adoption. This suggests that these promotion strategy groups would not greatly influence GBTs adoption within the Ghanaian construction industry. The findings might be associated with the fact that effective green building regulations and incentives were regarded as more important to promote the adoption of GBTs than strategies that are linked to awareness and education.

This research highlights the need to reinforce the government's participation in promoting GBTs adoption. Using the promotion strategies of "government regulations and standards" and "incentives and R&D support" to overcome the government-related barriers may significantly help to promote the GBTs adoption. Similarly, it could be concluded that companies, such as developer, contractor, and consultant companies, have a key role to play in the adoption and promotion of GBTs, so they should consider the potential benefits of GBTs and be committed to GBTs adoption. This study has investigated the influences of various kinds of barriers, drivers, and promotion strategies on GBTs adoption. Based on the findings, an implementation strategy (IPS) for the promotion of GBTs adoption is proposed and illustrated in Fig. 6. This IPS has been proposed based on the findings from Ghana. Though it might be useful for other countries, following this study's methodology, similar IPSs could be developed for any other country. To ensure the effectiveness of the proposed IPS, only the issues that were found to be significantly linked to the GBTs adoption were included in the IPS. Moreover, since it is only when potential adopters are motivated to adopt GBTs that they will think about the potential barriers (Potbhare et al., 2009), the identification of the significant drivers of the GBTs adoption is put as the first step within the IPS. As the significant drivers can motivate and lead companies to implement GBTs, it is necessary to promote them in the industry and the public. Identification of the significant barriers is the second step in the IPS, and the third step is the identification of the significant strategies to remove the barriers and promote GBTs adoption. A validation of the proposed IPS via a validation survey with five of the industry professionals who participated in the questionnaire survey for this study indicated that the IPS is credible and reasonable. Thus, policy makers, practitioners, and advocates can apply this IPS in their efforts to promote the adoption of GBTs in the construction industry.

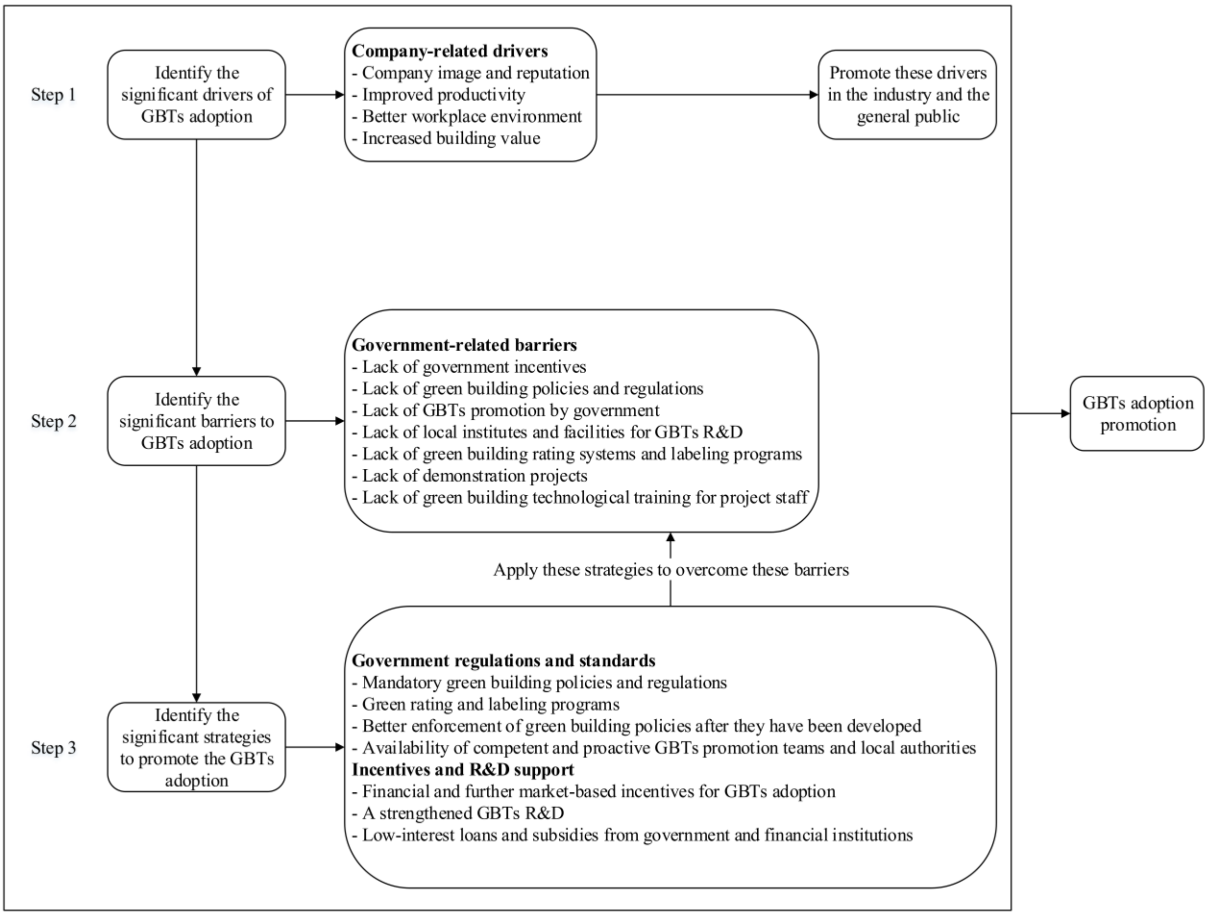


Fig. 6. An implementation strategy to promote GBTs adoption.

6. Conclusions

GBTs adoption in the construction industry has been documented as a critical step towards global sustainable development. Various barriers, drivers, and promotion strategies influence GBTs adoption inside the construction industry. However, little is known about the quantitative influences of barriers, drivers, and promotion strategies upon GBTs adoption. This study aimed at examining and modeling the quantitative influences of various types of barriers, drivers, and promotion strategies upon GBTs adoption within the Ghanaian construction industry. The data were collected via a questionnaire survey with 43 professionals with green building experience. PLS-SEM was used to analyze the data and the results showed that government-related barriers have a significant negative influence on GBTs adoption. Additionally, the results indicated that company-related drivers have a significant positive influence on GBTs adoption. Furthermore, it was found that "government regulations and standards" and "incentives and R&D support" are two promotion strategies that would have significant positive influences on GBTs adoption.

The practical implication is that to promote GBTs adoption in Ghana, the government needs to take a proactive role. For example, if incentives are provided for GBTs adoption, the lack of government incentives barrier can be addressed, and stakeholders would be motivated to adopt GBTs. Likewise, the lack of green building policies and regulations barrier could be addressed if the government and other public policy makers enact mandatory green building policies and regulations that would form regulatory pressure for companies and stakeholders to adopt GBTs. The policy makers should also promote GBTs R&D within both the public and private sectors. As per the results, company-related drivers are the major driver of the GBTs adoption. Thus, it may be necessary for companies to fully support and promote GBTs adoption because that may help them enhance their public image and reputation, improve their productivity, and gain other benefits.

The findings and models resulting from this research could be of great value and utility for researchers, policy makers, industry practitioners, and advocates seeking empirical quantitative evidence and explanations vis-à-vis the influences of barriers, drivers, and promotion strategies upon GBTs adoption within the construction industry. A clear understanding of which barriers, drivers, and promotion strategies could significantly influence GBTs adoption is beneficial to the successful adoption and promotion of GBTs in the construction industry. The awareness of the barriers and promotion strategies that are significantly correlated to GBTs adoption can aid policy makers and advocates to devise strategies to mitigate the barriers and hence promote the GBTs adoption. The appreciation of the drivers may help developer, contractor, and consultant companies understand the important benefits GBTs adoption could offer, and thereafter help them make more informed decisions vis-à-vis whether or not to adopt GBTs. To the green building body of knowledge, the key contribution this study makes is developing quantitative models that explicate how various types of barriers, drivers, and promotion strategies influence GBTs adoption in the construction industry.

Though the research aim was achieved, there are some limitations to the conclusions. First, although the sample was adequate to perform the PLS-SEM, it is nevertheless a relatively small sample. However, the findings of this study still provide invaluable insights into the influences of different types of barriers, drivers, and promotion strategies on GBTs adoption and, when appropriately used, would definitely help in promoting GBTs adoption. In addition, because of the lack of a sampling frame for this study, the nonprobability sampling approach was used. In spite of the inherent limitation, this sampling approach was suitable for selecting respondents upon the basis of their willingness to participate in the research, rather than selecting them from the population randomly. Lastly, since the findings were mainly interpreted within the context of Ghana, there might be some limitations on generalizations, which is a common problem of country-specific studies.

Nonetheless, the findings and implications of this research may be useful to policy makers, practitioners, stakeholders, and advocates in other, especially developing, countries around the world. In addition, this study may be useful to foreign and international organizations interested in implementing and promoting GBTs within Ghana. Based on the findings, an implementation strategy that could help policy makers, practitioners, and advocates promote GBTs adoption within the construction industry was proposed. While this implementation strategy could help to promote GBTs adoption within Ghana at this early stage of GBTs adoption and development, when the GBTs adoption activity becomes more mature, similar future studies should be done. These future studies are necessary because the barriers and drivers might change over time and, therefore, they might help to refine and improve the promotion strategies as well as the overall implementation strategy. Moreover, as part of the findings of this research, invaluable insights are offered into strategies to promote GBTs adoption. However, this research did not touch on the way forward for the government to implement these strategies, therefore warranting future research in this direction. Besides, the method in this study could be adopted to investigate the influences of barriers, drivers, and promotion strategies upon GBTs adoption in other countries, and the findings could be based upon to propose localized implementation strategies to help to more efficiently promote the widespread adoption of GBTs within those countries.

Acknowledgements

This paper forms part of a large Ph.D. research project aimed at promoting GBTs adoption within a developing country, Ghana. The authors acknowledge that this paper shares a similar background and methodology with other related papers published by the authors, but with different scopes and objectives. The authors would like to thank the Department of Building and Real Estate of The Hong Kong Polytechnic University for funding this research. The authors are also thankful to the industry professionals who participated in the questionnaire survey, and to Mr. Robert Quansah-Opirim for his invaluable help in the data collection. Finally, we are extremely grateful to the editors and anonymous reviewers whose invaluable comments and suggestions substantially helped in improving the quality of this paper.

References

Ackroyd, S., and Hughes, J. A. (1981). *Data collection in context*, Longman, London, UK.

Agherdien, N. (2007). A Review of Theoretical Frameworks in Educational Information and Communication Technology Research at Leading South African universities. Master's Thesis, Faculty of Education, University of Johannesburg, South Africa.

Agyarko, K. (2013). Towards Efficient Lighting Market, The Case of Ghana. Ghana Energy Commission. Presented at the ECOWAS Regional Workshop Initiatives on Standards and Labelling, Efficient Lighting and Energy Efficiency in Building.

Aibinu, A. A., and Al-Lawati, A. M. (2010). Using PLS-SEM technique to model construction organizations' willingness to participate in e-bidding. *Automation in Construction*, 19(6), 714-724.

Aibinu, A. A., Ling, F. Y. Y., and Ofori, G. (2011). Structural equation modelling of organizational justice and cooperative behaviour in the construction project claims process: contractors' perspectives. *Construction Management and Economics*, 29(5), 463-481.

Aktas, B., and Ozorhon, B. (2015). Green building certification process of existing buildings in developing countries: Cases from Turkey. *Journal of Management in Engineering*, 31(6), doi:10.1061/(ASCE)ME.1943-5479.0000358.

Al Horr, Y., Arif, M., Kaushik, A., Mazroei, A., Katafygiotou, M., and Elsarrag, E. (2016). Occupant productivity and office indoor environment quality: A review of the literature. *Building and Environment*, 105, 369-389.

ArchDaily. (2015). One Airport Square/Mario Cucinella Architects. https://www.archdaily.com/777642/one-airport-square-mario-cucinella-architects (Nov. 11, 2017).

Blayse, A. M., and Manley, K. (2004). Key influences on construction innovation. *Construction Innovation*, 4(3), 143-154.

Bubbs, D. (2017). Lessons in Green Building from Africa's First LEED-Certified Hospital. https://www.fastcodesign.com/3067054/lessons-in-green-building-from-africas-first-leed-certified-hospital (Feb. 4, 2017).

Byrne, B. M. (2013). *Structural equation modeling with AMOS: Basic concepts, applications, and programming*, Routledge, New York, US.

Chan, A. P. C., Darko, A., Ameyaw, E. E., and Owusu-Manu, D. G. (2016). Barriers affecting the adoption of green building technologies. *Journal of Management in Engineering*, 33(3), doi:10.1061/(ASCE)ME.1943-5479.0000507.

Chan, A. P. C., Darko, A., and Ameyaw, E. E. (2017). Strategies for promoting green building technologies adoption in the construction industry—An international study. *Sustainability*, 9(6), 969, doi:10.3390/su9060969.

Chan, A. P. C., Darko, A., Olanipekun, A. O., and Ameyaw, E. E. (2018). Critical barriers to green building technologies adoption in developing countries: The case of Ghana. *Journal of Cleaner Production*, 172, 1067-1079.

Chin, W. W. (1998). The partial least squares approach to structural equation modeling. *Modern methods for business research*, G. A. Marcoulides, ed., Lawrence Erlbaum Associates, Mahwah, New Jersey, US, 295–335.

Darko, A., and Chan, A. P. C. (2016). Critical analysis of green building research trend in construction journals. *Habitat International*, 57, 53-63.

Darko, A., and Chan, A. P. C. (2017). Review of barriers to green building adoption. *Sustainable Development*, 25(3), 167-179.

Darko, A., and Chan, A. P. C. (2018). Strategies to promote green building technologies adoption in developing countries: The case of Ghana. *Building and Environment*, 130, 74-84.

Darko, A., Chan, A. P. C., Ameyaw, E. E., He, B. J., and Olanipekun, A. O. (2017a). Examining issues influencing green building technologies adoption: The United States green building experts' perspectives. *Energy and Buildings*, 144, 320-332.

Darko, A., Chan, A. P. C., Gyamfi, S., Olanipekun, A. O., He, B. J., and Yu, Y. (2017c). Driving forces for green building technologies adoption in the construction industry: Ghanaian perspective. *Building and Environment*, 125, 206-215.

Darko, A., Zhang, C., and Chan, A. P. C. (2017b). Drivers for green building: A review of empirical studies. *Habitat International*, 60, 34-49.

Davison, A. C., and Hinkley, D. V. (1997). *Bootstrap methods and their application*, Cambridge University Press, Cambridge, UK.

Djokoto, S. D., Dadzie, J., and Ohemeng-Ababio, E. (2014). Barriers to sustainable construction in the Ghanaian construction industry: consultants' perspectives. *Journal of Sustainable Development*, 7(1), 134-143.

DuBose, J. R., Bosch, S. J., and Pearce, A. R. (2007). Analysis of state-wide green building policies. *Journal of Green Building*, 2(2), 161-177.

Durdyev, S., Zavadskas, E. K., Thurnell, D., Banaitis, A., and Ihtiyar, A. (2018). Sustainable construction industry in Cambodia: Awareness, drivers, and barriers. *Sustainability*, 10(2), 392, doi:10.3390/su10020392.

Dwaikat, L. N., and Ali, K. N. (2016). Green buildings cost premium: A review of empirical evidence. *Energy and Buildings*, 110, 396-403.

Ekanayake, L. L., and Ofori, G. (2004). Building waste assessment score: design-based tool. *Building and Environment*, 39(7), 851-861.

Fernández, Y. F., López, M. F., and Blanco, B. O. (2018). Innovation for sustainability: the impact of R&D spending on CO_2 emissions. *Journal of Cleaner Production*, 172, 3459-3467.

Fornell, C., and Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 18(1), 39-50.

Gou, Z., Lau, S. S. Y., and Prasad, D. (2013). Market readiness and policy implications for green buildings: case study from Hong Kong. *Journal of Green Building*, 8(2), 162-173.

Gyamfi, S., Diawuo, F. A., Kumi, E. N., Sika, F., and Modjinou, M. (2018). The energy efficiency situation in Ghana. *Renewable and Sustainable Energy Reviews*, 82, 1415–1423.

Hair, J. F., Anderson, R. E., Tatham, R. L., and Black, W. C. (1998). *Multivariate data analysis with readings*, Prentice-Hall, Englewood Cliffs, New Jersey, US.

Hair, J. F., Hult, G. T. M., Ringle, C. M., and Sarstedt, M. (2014b). *A primer on partial least squares structural equation modeling*, Sage, Thousand Oaks, California, US.

Hair, J. F., Sarstedt, M., Hopkins, L., and Kuppelwieser, V. G. (2014a). Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research. *European Business Review*, 26(2), 106-121.

Helm, S., Eggert, A., and Garnefeld, I. (2009). Modelling the impact of corporate reputation on customer satisfaction and loyalty using PLS, in Esposito, V.V., Chin, W.W., Henseler, J. and Wang, H. (Eds), *Handbook of Partial Least Squares: Concepts, Methods, and Applications*, Springer, Berlin, Germany.

Hosseini, M. R., Banihashemi, S., Martek, I., Golizadeh, H., and Ghodoosi, F. (2018). Sustainable delivery of megaprojects in Iran: Integrated model of contextual factors. *Journal of Management in Engineering*, 34(2), doi:10.1061/(ASCE)ME.1943-5479.0000587.

Hulland, J. (1999). Use of partial least squares (PLS) in strategic management research: A review of four recent studies. *Strategic Management Journal*, 20(2), 195-204.

Hwang, B. G., Zhu, L., and Tan, J. S. H. (2017). Green business park project management: Barriers and solutions for sustainable development. *Journal of Cleaner Production*, 153, 209-219.

IEA. (2013). Modernising Building Energy Codes. https://www.iea.org/publications/freepublications/publication/PolicyPathwaysModernisingBuildingEnergyCodes.pdf (Oct. 25, 2017).

Issa, M. H., Rankin, J. H., and Christian, A. J. (2010). Canadian practitioners' perception of research work investigating the cost premiums, long-term costs and health and productivity benefits of green buildings. *Building and Environment*, 45(7), 1698-1711.

Jack, P. C. K., Russell, C. H. C., and Bert, B. (2001). Validation of trace-driven simulation models: bootstrap tests. *Management Science*, 47(11), 1533-1538.

Kates, R., and Clark, W. (1999). *Our common journey: A transition toward sustainability*, National Academy Press, Washington, DC, US.

Lam, P. T., Chan, E. H., Chau, C. K., Poon, C. S., and Chun, K. P. (2009). Integrating green specifications in construction and overcoming barriers in their use. *Journal of Professional Issues in Engineering Education and Practice,* 135(4), 142-152.

Li, Y., Chen, X., Wang, X., Xu, Y., and Chen, P. H. (2017). A review of studies on green building assessment methods by comparative analysis. *Energy and Buildings*, 146, 152-159.

Lim, B. T., Ling, F. Y., Ibbs, C. W., Raphael, B., and Ofori, G. (2012). Mathematical models for predicting organizational flexibility of construction firms in Singapore. *Journal of Construction Engineering and Management*, 138(3), 361-375.

Love, P. E., Niedzweicki, M., Bullen, P. A., and Edwards, D. J. (2012). Achieving the green building council of Australia's world leadership rating in an office building in Perth. *Journal of Construction Engineering and Management*, 138(5), 652-660.

Mao, C., Shen, Q., Pan, W., and Ye, K. (2015). Major barriers to off-site construction: The developer's perspective in China. *Journal of Management in Engineering*, 31(3), doi:10.1061/(ASCE)ME.1943-5479.0000246.

Miller, G. A. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological Review*, 63(2), 81-97.

Mulligan, T. D., Mollaoglu-Korkmaz, S., Cotner, R., and Goldsberry, A. D. (2014). Public policy and impacts on adoption of sustainable built environments: learning from the construction industry playmakers. *Journal of Green Building*, 9(2), 182-202.

Murari, K. (2015). *Impact of leadership styles on employee empowerment*, Partridge, India.

Ning, Y. (2014). Quantitative effects of drivers and barriers on networking strategies in public construction projects. *International Journal of Project Management*, 32(2), 286-297.

Nunnally, J. C. (1978). *Psychometric theory,* McGraw-Hill, New York, US.

Onuoha, I. J., Aliagha, G. U., and Rahman, M. S. A. (2018). Modelling the effects of green building incentives and green building skills on supply factors affecting green commercial property investment. *Renewable and Sustainable Energy Reviews,* 90, 814-823.

Ott, R. L., and Longnecker, M. (2010). *An introduction to statistical methods and data analysis,* Brooks/Cole, Belmont, California, US.

Ozdemir, M. H. (2000). An Alternative Incentive System to Improve Productivity at The Turkish Naval Shipyards. Ph.D. Thesis, Naval Postgraduate School, Monterey, California, US.

Ozorhon, B., and Oral, K. (2017). Drivers of innovation in construction projects. *Journal of Construction Engineering and Management,* 143(4), doi:10.1061/(ASCE)CO.1943-7862.0001234.

Patton, M. Q. (2001). *Qualitative research and evaluation components,* Sage, Thousand Oaks, California, US.

Paul, W. L., and Taylor, P. A. (2008). A comparison of occupant comfort and satisfaction between a green building and a conventional building. *Building and Environment,* 43(11), 1858-1870.

Potbhare, V., Syal, M., and Korkmaz, S. (2009). Adoption of green building guidelines in developing countries based on US and India experiences. *Journal of Green Building,* 4(2), 158-174.

Qian, Q. K., Fan, K., and Chan, E. H. (2016). Regulatory incentives for green buildings: gross floor area concessions. *Building Research & Information,* 44(5-6), 675-693.

Rocky Mountain Institute. (1998). Greening the Building and the Bottom Line: Increasing Productivity through Energy Efficient Design. http://library.uniteddiversity.coop/Ecological_Building/Greening_the_Building_and_the_Bottom_Line.pdf. (Nov. 13, 2017).

Sadiq, M. (2018). Solar water heating system for residential consumers of Islamabad, Pakistan: A cost benefit analysis. *Journal of Cleaner Production*, 172, 2443-2453.

Shan, M., Hwang, B. G., and Zhu, L. (2017). A global review of sustainable construction project financing: policies, practices, and research Efforts. *Sustainability*, 9(12), 2347, doi:10.3390/su9122347.

Shazmin, S. A. A., Sipan, I., and Sapri, M. (2016). Property tax assessment incentives for green building: A review. *Renewable and Sustainable Energy Reviews*, 60, 536-548.

Shen, L., Zhang, Z., and Long, Z. (2017b). Significant barriers to green procurement in real estate development. *Resources, Conservation and Recycling*, 116, 160-168.

Shen, L., Zhang, Z., and Zhang, X. (2017a). Key factors affecting green procurement in real estate development: a China study. *Journal of Cleaner Production*, 153, 372-383.

Shi, Q., Zuo, J., Huang, R., Huang, J., and Pullen, S. (2013). Identifying the critical factors for green construction–an empirical study in China. *Habitat International*, 40, 1-8.

Simon, M. K., and Goes, J. (2011). Developing A Theoretical Framework. http://www.comunidades.upev.ipn.mx/RCTS/SemI%20Doctorado/Developing%20aTheoreticalFrameworkSimonMK.pdfi (May 20, 2015).

The State of Michigan. (2010). House Bill 5375 (2009): Public Act 242 of 2009. Michigan Legislature. http://www.legislature.mi.gov/(S(ljc04d45uf34n45ndyzfoiw))/mileg.aspx ?page=GetObject&objectName=2009-HB-5375 (Dec. 14, 2014).

USEPA. (2016). Definition of Green Building. https://archive.epa.gov/greenbuilding/web/html/about.html (Mar. 28, 2017).

Wilkins, J. R. (2011). Construction workers' perceptions of health and safety training programmes. *Construction Management and Economics*, 29(10), 1017-1026.

Wong, J. K. W., San Chan, J. K., and Wadu, M. J. (2016). Facilitating effective green procurement in construction projects: An empirical study of the enablers. *Journal of Cleaner Production*, 135, 859-871.

WorldGBC. (2018). What is Green Building? http://www.worldgbc.org/what-green-building (Apr. 29, 2018).

Xiong, B., Skitmore, M., and Xia, B. (2015). A critical review of structural equation modeling applications in construction research. *Automation in Construction*, 49, 59-70.

Yudelson, J. (2007). *Predicting the growth of green buildings using Diffusion of Innovation Theory*, Yudelson Associates, Tuscon, Arizona, US.

Zailani, S., Govindan, K., Shaharudin, M. R., and Kuan, E. E. L. (2017). Barriers to product return management in automotive manufacturing firms in Malaysia. *Journal of Cleaner Production*, 141, 22-40.

Zhang, L., Wu, J., and Liu, H. (2018). Turning green into gold: A review on the economics of green buildings. *Journal of Cleaner Production*, 172, 2234-2245.

Zhang, X. (2015). Green real estate development in China: State of art and prospect agenda—A review. *Renewable and Sustainable Energy Reviews*, 47, 1-13.

Zhang, X., Shen, L., and Wu, Y. (2011). Green strategy for gaining competitive advantage in housing development: a China study. *Journal of Cleaner Production*, 19(2), 157-167.

Zhao, X., and Singhaputtangkul, N. (2016). Effects of firm characteristics on enterprise risk management: Case study of Chinese construction firms operating in Singapore. *Journal of Management in Engineering*, 32(4), doi:10.1061/(ASCE)ME.1943-5479.0000434.

Zhao, X., Hwang, B. G., and Gao, Y. (2016). A fuzzy synthetic evaluation approach for risk assessment: a case of Singapore's green projects. *Journal of Cleaner Production*, 115, 203-213.

Zhao, X., Hwang, B. G., Low, S. P., and Wu, P. (2014). Reducing hindrances to enterprise risk management implementation in construction firms. *Journal of Construction Engineering and Management,* 141(3), doi:10.1061/(ASCE)CO.1943-7862.0000945.

Zitzler, E., Deb, K., and Thiele, L. (2000). Comparison of multiobjective evolutionary algorithms: Empirical results. *Evolutionary Computation*, 8(2), 173-195.

Zuo, J., and Zhao, Z. Y. (2014). Green building research–current status and future agenda: A review. *Renewable and Sustainable Energy Reviews*, 30, 271-281.